Space Weather Technical Forecast

Issued on Sunday, 03 December 2023 at 01:27 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of further M-Class flares (R1-R2 Blackouts). G1-G2 (Minor-Moderate geomagnetic storms) likely day 2 and 3 (04 and 05 Dec).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity is at Low levels with the largest flare of the previous 24 hours a C4.4 flare from the long-period decline of the M1.0 flare from AR3500 that peaked at 01/2120 UTC. There are seven sunspots on the visible disc. AR3500 (Eki/Beta-Gamma) in the southwest remains the largest and most significant region, however some slight decay was observed during the period with the loss of its weak delta spot and reduction in penumbra area. AR3509 (Cso/Beta) in the northwest developed, then began to simplify its magnetic configuration. AR3492 and AR3502 rotated over the western limb. The remaining regions on the visible disc are all mature and stable unipolar "H" spots.

Despite a number of CME signatures evidenced in coronagraph imagery during the past 24 hours, none are considered Earth-directed.

Solar Wind / Geomagnetic Activity: Solar wind speeds, as observed by DSCOVR at L1 began the period at Elevated levels, with a peak of 526km/s at 02/0000 UTC. Speeds declined through the period to become Slightly Elevated, around 420km/s by the end of the UTC day. Density was Above Average to start, peaking at around 25 pppc at 02/0045 UTC, before later reducing to Average or Below Average levels. The Interplanetary Magnetic Field (IMF), Bt, was initially Strong, peaking at 18nT at 02/0001 UTC. IMF gradually weakened, becoming Moderate (around 9nT) by the end of the period. The north-south component of the IMF (Bz), was Moderately negative at first (peak -12nT at 02/0044 UTC) before becoming Moderately positive from 02/0700 UTC onwards with a peak of +12nT at 02/1354 UTC. Phi angle was negative (towards the Sun) throughout.

Resultant Geomagnetic activity was initially at G1/Minor Storm levels from 02/0000-0300 UTC, then Active (Kp4) from 02/0300-0600 UTC, but have eased to Quiet (Kp 0-2) levels since then.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux has been predominantly Background. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) with a declining then steady trend. The observation at 02/0000 UTC was 1.09e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be Low with a chance for isolated M-flares (R1-R2 Blackout), and a very slight chance of an isolated X-class flare (R3 Blackout) on days 1-2 (03-04 Dec). The bulk of the significant flare risk is attributed to AR3500 in the southwest.

Solar Wind / Geomagnetic Activity: A CME that left the sun late on 01 Dec has a chance to give a glancing impact at Earth late day 2 (04 Dec) or early day 3 (05 Dec), otherwise no Earth-directed CMEs feature in the forecast period. Solar winds are continuing to ease following the notable CME arrival on 01 Dec. Speeds should fall from Slightly Elevated to Background levels on day 2 (04 Dec) and remain at similar levels until the next solar wind enhancement from a

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large coronal hole currently moving into the western hemisphere. Speeds should increase to Elevated or Strong levels with this feature, starting from late day 2 (04 Dec) or early day 3 (05 Dec) and likely persisting into day 4 (06 Dec).

Geomagnetic activity is expected to be Quiet to Unsettled on day 1 (03 Dec) and much of day 2 (04 Dec), then forecast to increase to G1-G2/Minor-Moderate Storm (Kp5-6) levels late day 2 or day 3 (05 Dec). Following peak geomagnetic activity, indices should fall to Active to Unsettled by the end of day 3 (05 Dec), before becoming Quiet to Unsettled on day 4 (06 Dec).

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at Background levels with just a very Slight Chance of exceeding the S1 Minor Radiation Storm threshold should any significant flares or notable filament eruptions take place.

Electron flux is at largely Background levels following recently enhanced geomagnetic activity. Some recovery of flux to Moderate or High levels at diurnal peak is possible from day 1 (03 Dec) and then probable from day 2 (04 Dec) onwards. Electron flux is then likely to decrease to Background levels again as geomagnetic activity increases with the arrival of a coronal hole HSS, late on day 2 or early day 3 (04 or 05 Dec) along with possible minor CME influences.

The associated 24 hour electron fluence is expected to remain below the Active threshold (1e8 integrated pfu). However, a rising trend is likely between day 1-3 (03-05 Dec) with a very Slight Chance of exceeding the Active threshold on day 2 and 3 (04 and 05 Dec).

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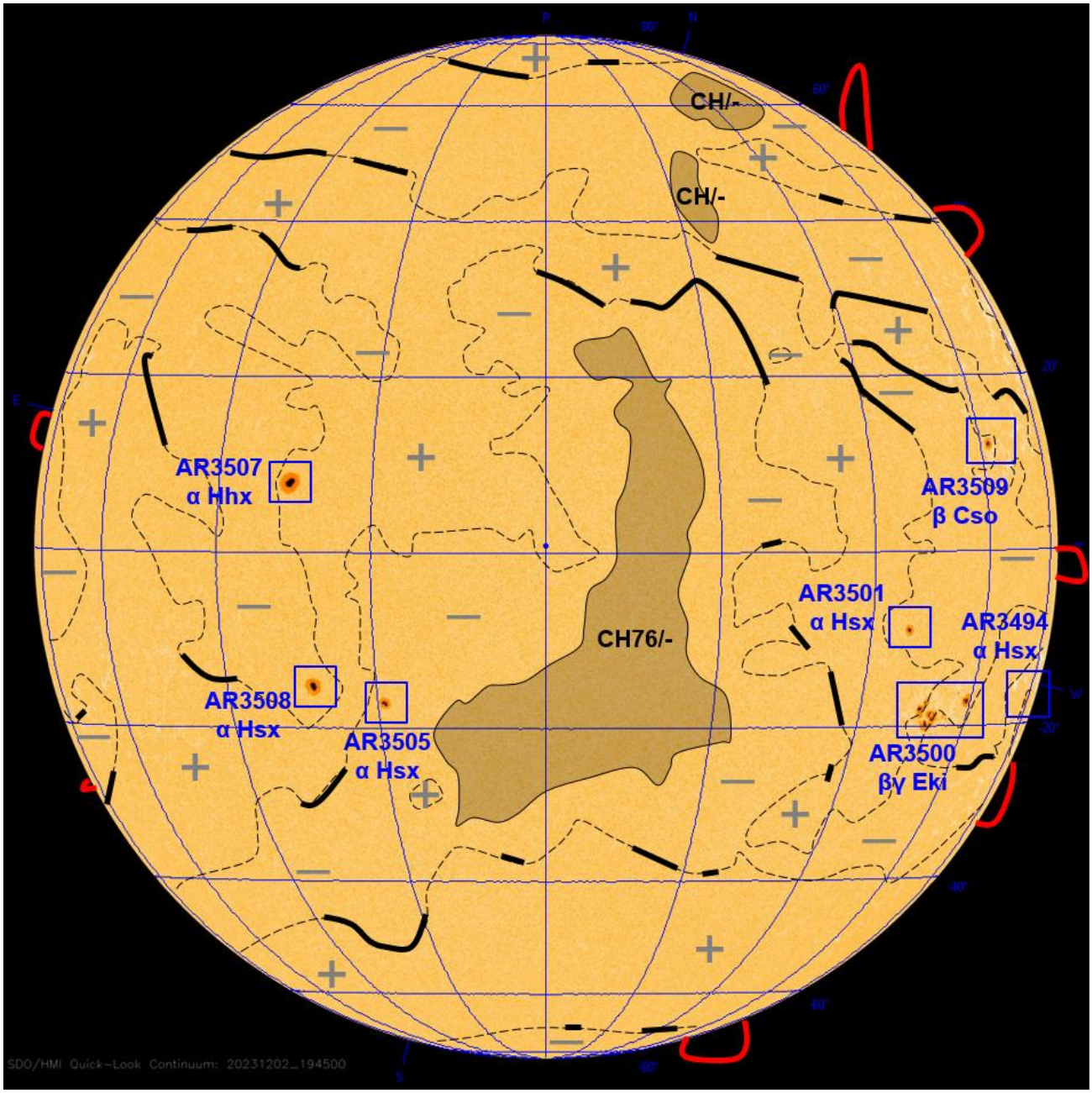
Figure 1. Solar Analysis Valid 02/1945 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A CME that left the sun in association with the M1.1 flare from AR3500 at 01/2120 UTC has been analysed and modelled. Although the majority of the ejecta is forecast to pass ahead of and below Earth orbit, there is a chance of a glancing blow late on day 2 (04 Dec) or early day 3 (05 Dec).

Solar winds have eased to Slightly Elevated levels as the residual effects of the notable CME arrival on 01 Dec continue to subside. Speeds should reduce further to become Background on day 1 (03 Dec). The next forecast enhancement is the arrival of a High Speed Stream (HSS) associated with the large CH76/-, currently crossing into the western hemisphere. The expected onset of this feature at Earth is late day 2 (04 Dec) or early day 3 (05 Dec). This is a persistent feature and similar in size and position to the previous rotation, however during the previous rotation a CME arrival masked the initial influence of the coronal hole. Elevated to Strong winds of around 550-650km/s are expected, though with slightly lower than average confidence in peak speeds from this feature. Elevated to Strong speeds should persist through to the end of day 4 (06 Dec).

Geomagnetic activity is expected to be Quiet to Unsettled on day 1 (03 Dec) and much of day 2 (04 Dec), then forecast to increase to G1-G2/Minor-Moderate Storm (Kp5-6) levels late day 2 or day 3 (05 Dec). Following peak geomagnetic activity, indices should fall to Active to Unsettled by the end of day 3 (05 Dec), before becoming Quiet to Unsettled on day 4 (06 Dec).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	70	50	5
Strong	G3	No	1	10	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
02/0440 UTC	Partial Halo	M1.0 Flare AR3500	SW	585 km/s	04/1800 UTC	Chance of a glancing blow, with limited shock expected

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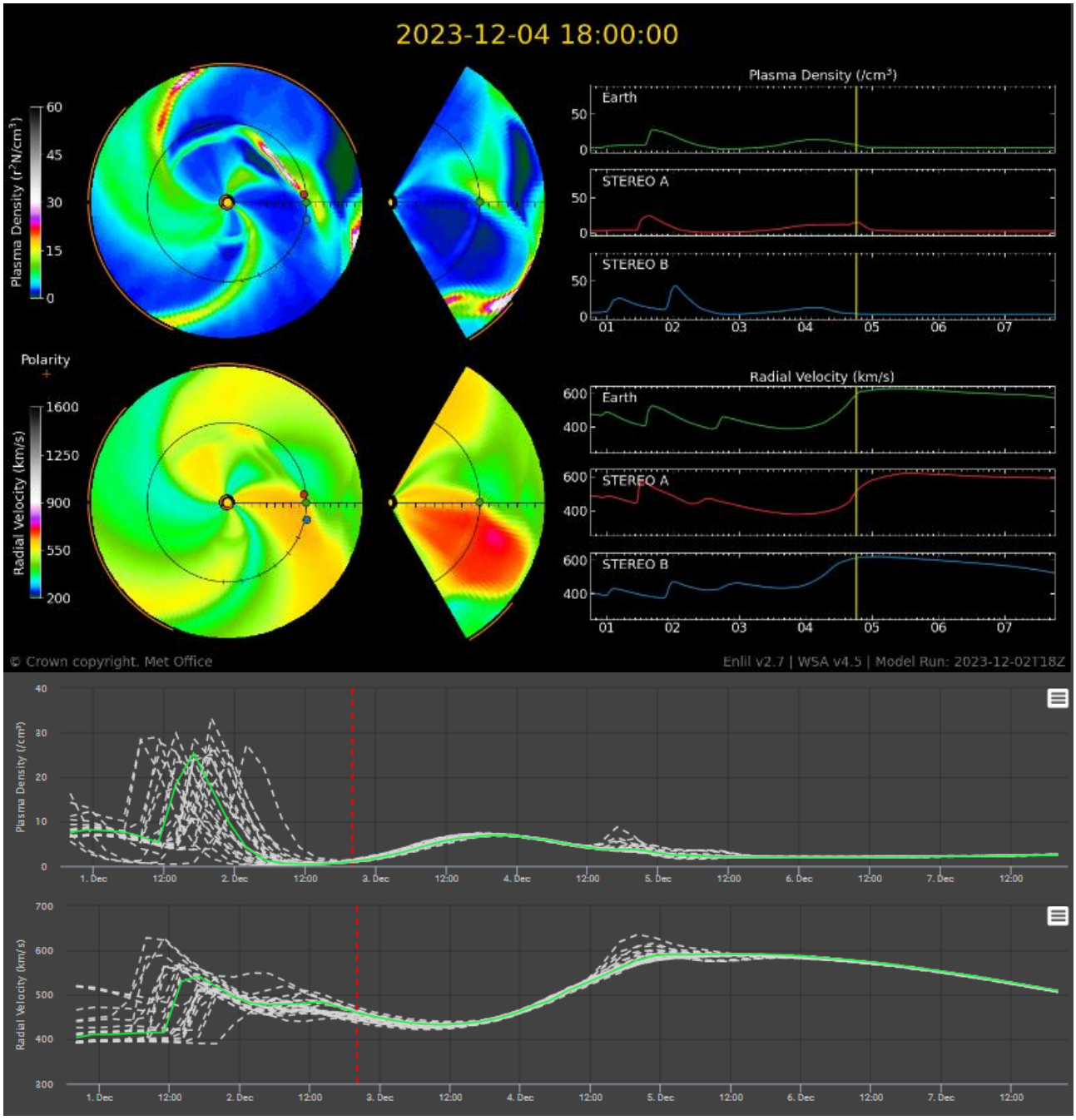
Figure 2: MOSWOC Enlil and Ensemble forecast, set to 04/1800 UTC, projected chance of arrival of CME from late 01 Dec.



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Radio Blackouts - X-Ray Flares:

The largest flare of the past 24 hours is a C4.4 flare from the long-period decline of the M1.0 flare from AR3500 that peaked at 01/2120 UTC.

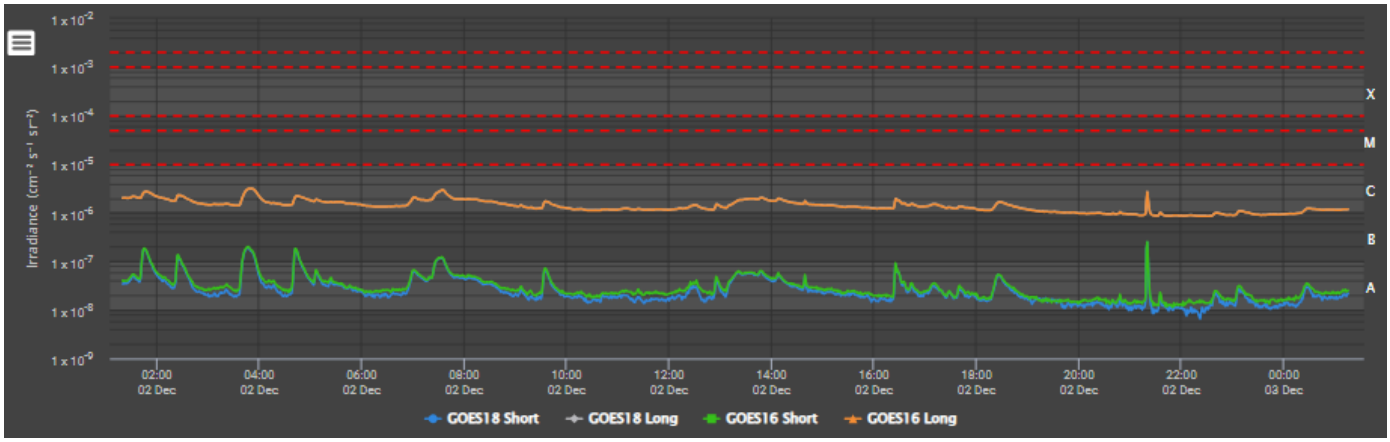
There are seven sunspots on the disc. AR3500 in the southwest remains the largest and most significant region, despite some slight decrease in overall size. There is a cluster of opposing polarity spots in the eastern part of the group, although previous delta spots are no longer evident. AR3509 in the northwest has simplified to Cso/Beta with the decay of some of its intermediate spots. The remaining regions on the visible disc are all mature and stable unipolar "H" spots.

A number of sunspots in the western hemisphere, including AR3500, are due to rotate over the western limb in the forecast period. No significant returning or new regions are expected to rotate over the eastern horizon in the coming days, so the likelihood of significant flares reduces overall in the absence of any notable developments on the visible disc.

Solar activity is expected to be Low with a chance for isolated M-flares (R1-R2 Blackout), and a very slight chance of an isolated X-class flare (R3 Blackout) on days 1-2 (03-04 Dec).

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	45	45	30	10
Very Active	R3 to R5 X Class	No	5	5	3	1

Figure 3: GOES 16/18 X-Ray flux for past 24 hours



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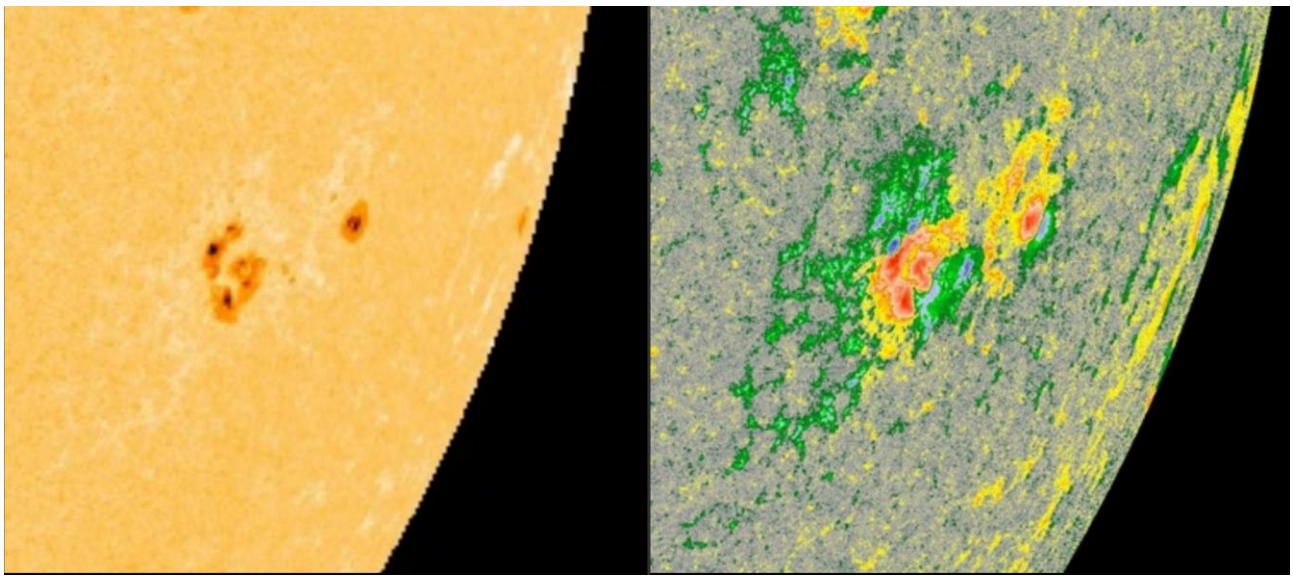
Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background and expected to remain at this level. However, with the number of spots and filaments on the disc there is a chance of flux increasing in response to any significant flares or eruptions. The main risk is from AR3500, in the southwest disc. This was the source of an M9.8 flare late on 28 Nov, and while no proton response was observed at Earth on this occasion, any further significant flares will also have the potential to increase the observed proton flux. The risk should reduce by day 4 (05 Dec) as AR3500 rotates over the western horizon onto the far-side of the Sun.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	10	10	10	5
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: HMI Intensitygram Flattened (left) and Colorized Magnetogram (Right) for AR3500 at 03/0030 UTC.



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High Energy Electrons Event (≥ 2MeV):

Electron flux is at largely Background levels following recently enhanced geomagnetic activity. Some recovery of flux to Moderate or High levels at diurnal peak is possible from day 1 (03 Dec) and then probable from day 2 (04 Dec) onwards. Electron flux is then likely to decrease to Background levels again as geomagnetic activity increases with the arrival of the HSS from CH76/-, late on day 2 or early day 3 (04 or 05 Dec) along with possible minor CME influences.

The associated 24 hour electron fluence is expected to remain below the Active threshold (1e8 integrated pfu). However, a rising trend is likely between day 1-3 (03-05 Dec) with a very Slight Chance of exceeding the Active threshold on day 2 and 3 (04 and 05 Dec).

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	10	10	1
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: GOES 16 >2MeV Electron Flux (top) and MOSWOC REFM forecast with recurrence (below)

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